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SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR MAY, 1916.

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GENERAL PRESSURE DISTRIBUTION OVER THE UNITED STATES AND CANADA, INCLUDING THE HAWAIIAN AND ALEUTIAN ISLANDS, ALASKA, AND THE WESTERN PORTIONS OF THE MIDDLE ATLANTIC OCEAN.

Pressure conditions over the Pacific Ocean and Alaska were quite well defined during the month with alternations of high and low pressure, each lasting about one week. An exception should be noted in pressure conditions in the vicinity of the Aleutian Islands where there was but a single depression of well-defined character, occurring from the 17th to 19th, inclusive. Otherwise pressure in this vicinity was high, as a rule, with occasional approaches to normal conditions. There were no great disturbances during the month. It should be noted, however, as a departure from the more usual conditions that the high and low areas over the North and the South Pacific were, as a rule, coincident throughout the month.

As would be expected from conditions over the Pacific Ocean, there was also an absence of severe disturbances over the United States. The most marked ones were those that moved over the extreme northern portions of the country, although there were several others of only slightly less intensity that developed in the Plateau Region and moved eastward and northeastward by way of the central Plains States and the Upper Lake Region. On the whole pressure was below normal during the month, only the second decade showing any positive departures of consequence and these only over the extreme north. Over the North Atlantic Ocean, as indicated by the barometric readings at Horta, Bermuda and Turks Island, there were alternate waves of moderately low and moderately high pressure, but nothing deserving of special mention.

STORM WARNINGS.

Small-craft warnings were ordered on the morning of May 4 on Lake Superior for fresh to strong southerly winds that were expected from the eastward movement of a low pressure area from the Canadian Northwest. Strong winds, really sufficient to justify a warning of a moderate storm, occurred over western Lake Superior and northern Lake Michigan, but they were of very short duration. On the evening of the 7th another disturbance from the Canadian Northwest had apparently reached eastern Minnesota and northwest warnings were ordered at 10 p. m. for western Lake Superior and northern Lake Michigan. Reports from Manitoba were missing and it afterwards developed that the storm center was really over the latter section, with lower pressure. Knowledge of this fact would have permitted the display over Lake Huron and southern Lake Michigan to have been made twelve hours earlier. On the morning of the 8th the disturbance was over northern Lake Superior with still further increased energy and the warnings were extended throughout the Lake Region, the direction being north-

west on the Upper Lakes and southwest on the Lower Lakes. Westerly gales occurred generally, except on Lake Ontario, and at 8 p. m. of the 8th the storm center was over the lower St. Lawrence Valley. Northwest warnings were then ordered on the Atlantic coast from Delaware Breakwater to New York and on the following day moderate northwest gales occurred as forecast. By the evening of the 9th still another Canadian Northwest disturbance of more decided character than its two immediate predecessors had reached eastern South Dakota and storm warnings were ordered for the Upper Lakes, except southern Lake Huron, south and southwest gales being forecast for Lakes Superior and Michigan. On the following morning when the disturbance was central over eastern Manitoba the storm warnings were extended to southern Lake Huron and the Lower Lakes. Severe southwest and west gales occurred, lasting until the evening of the 11th, a number of stations reporting wind velocities of more than 50 miles an hour, with a maximum of 72 miles at Buffalo. Warnings had, of course, been continued and changed to northwest and the last (from Erie to Oswego) were not lowered until 9 p. m. of the 11th. On the evening of the 10th, when the storm was still over Lake Superior, southwest warnings were ordered on the Atlantic coast from Delaware Breakwater to Portland and on the following morning were extended to Eastport. Strong winds occurred as forecast.

On the morning of the 10th there were evidences of the approach of a disturbance toward Cuba. It did not appear to be of serious character and no mention was made of it until the evening of the 13th, when it was approaching the southern Florida coast. Advisory warnings were then issued to Atlantic and Gulf ports, and delay in shipping suggested until further advices. On the following morning (the 14th) with steadily falling, although not very low, pressure over Florida, with increasing easterly winds, northeast storm warnings were ordered from Jacksonville to Fortress Monroe. During the day moderate gales occurred on the northern Florida coast and fresh to strong winds on the Georgia and South Carolina coasts, but nothing of consequence farther northward. The disturbance continued to move slowly up the coast with steadily falling pressure and some rain but without strong winds, and on the morning of the 16th it was central over eastern South Carolina, with a barometer reading of 29.70 inches at Charleston. Special observations were called for and advisory warnings issued. Northeast warnings were ordered to be displayed at 6 p. m. at Block Island and Nantucket, and at 9:45 p. m. they were extended along the coast from Sandy Hook to Eastport. The storm had now increased considerably in energy, and on the morning of the 17th was central over southern New England with lowest barometer reading of 29.32 inches, and moderate gales had occurred from northern New Jersey to Cape Cod. These increased in severity, accompanied by rain, and by the evening of the 17th strong gales had occurred on the coast from New York to Maine, the storm center at that time being over the western Maine coast (29.28 inches). After this time there was some interference on the part of the western storm next to be mentioned, and a consequent rapid

diminution in energy, although pressure continued comparatively low until the night of the 19th.

During the 10th, when the preceding western disturbance was over Lake Superior at about its greatest intensity, a disturbance formed over the extreme Southwest with marked high pressure on the north Pacific coast. The Southwest disturbance did not move rapidly, but pressure fell slowly and steadily to the northeastward with the high area moving across the northern tier of States, and finally by the evening of the 13th the disturbance was central over northern New Mexico with promise of more rapid development and with a steep gradient toward the high area that at the time was over Lake Superior. Northeast storm warnings were accordingly ordered at 9:45 p. m. on Lake Superior from Duluth, Minn., to Ashland, Wis., and northeast and southeast warnings on the following morning at the remainder of the Upper Lake stations. The storm at this time was central over eastern Kansas, and during the next 24 hours easterly gales occurred on western Lake Superior, but only moderately strong winds over the remainder of the Upper Lakes. As the disturbance was moving slowly, the warnings were continued on the 15th for an additional 24 hours, except over the extreme southern portions of Lakes Michigan and Huron, and during the 16th the winds subsided.

On the morning of the 18th a moderate disturbance from the extreme Southwest was central near the mouth of the Rio Grande, and there had been some strong thunderstorm winds at Galveston. One p. m. special observations from Gulf stations did not indicate anything unusual, but the disturbance evidently moved rapidly across the northern Gulf and pressure fell rapidly during the afternoon. Accordingly northeast and southeast warnings of strong easterly winds were ordered at 5 p. m. from Bay St. Louis, Miss., to Cedar Keys, Fla. These occurred before evening, mostly in the form of thunder-squalls, and by 8 p. m. only slight evidences of the disturbance remained. During the same time a disturbance had been developing over the middle Plateau. It did not move much until the evening of the 19th when it was central over western Colorado. By the following evening it was over southwestern Kansas with a fair high area over Lake Huron and, as a precaution, northeast warnings were ordered on Lake Michigan at 11 p. m. from Green Bay, Wis., to Michigan City, Ind. At 10:00 a. m. of the 21st, northeast and southeast warnings were ordered at the remaining Upper Lake stations, and at 4 p. m. southeast warnings at Lower Lake stations from Detroit to Erie. During the 21st the disturbance divided with a decided loss of energy, one section going to Iowa and thence northward to Minnesota, while the other section dissipated over northeastern Texas. Consequently the resulting winds on the Lakes, while strong, were by no means dangerous, and on the morning of the 22d the warnings were changed to "small craft."

On the morning of the 23d there was another Plateau disturbance over Nevada. It moved slowly eastward, and on the morning of the 25th it extended from eastern Colorado to eastern South Dakota with fair development. Northeast storm warnings were then ordered on Lake Superior from Duluth, Minn., to Ashland, Wis., and small craft warnings at remaining Lake Superior stations. During the day northeasterly gales occurred as forecast, diminishing during the night as pressure fell to the northwestward, and the disturbance lost its energy. The last warning of the month was a "small craft" on the 30th on the middle Atlantic and New England coasts, hoisted on

account of a depression that had come out of the unsettled barometric conditions of the few previous days in the extreme West and had moved to the upper St. Lawrence Valley. Fresh to moderately strong winds occurred.

FROST WARNINGS.

While cool weather prevailed during much of the month, there were no general and decided frost periods owing to the more or less persistent cloudiness. During the first three weeks frosts were forecast about one-half the time for some portions of the Northern States, and while some of these warnings were verified, others were not, and the general results were not satisfactory owing to the excessive cloudiness. Frost warnings during the last 10 days of the month were less frequent and more successful. A heavy frost on the 31st in Upper Michigan was not forecast owing to the absence on the morning of the 30th of the pronounced conditions that developed during the day.

DISTRICT WARNINGS DURING MAY.

Chicago district.—Frost warnings were issued for some portions of the Chicago forecast district on 16 days during the month. On the 1st warnings were issued for Wisconsin, western Illinois, east and north-central Iowa, and southwestern Missouri, and warning of frosts or freezing temperature for Montana. These warnings were verified except in southwestern Missouri. An area of high pressure with freezing temperature was overspreading the Northwest on the morning of the 2d, following a disturbance centered over Colorado. Accordingly frost warnings were issued for the northern and western portions of the district. These warnings were verified generally except in Wisconsin where precipitation occurred during the night. On the 3d warnings were sent only to central Illinois, as the high pressure area was moving far to the southward, and a marked disturbance was developing over the far Northwest. This disturbance was centered over Manitoba on the morning of the 4th and was followed by cooler weather. Frost warnings were issued for North Dakota and northwestern Minnesota, but failed of verification on account of the immediate development of another disturbance over the Northwest.

No further warnings were required until the 7th when a disturbance of much force was moving eastward near the northern border, and was followed by a High of the North Pacific type. Warnings were issued for Montana, Wyoming, the western portions of the Dakotas, and northwestern Nebraska. Frost occurred on the morning of the 8th, as predicted, except in western North Dakota, where fresh winds prevented frost formation, and warnings were issued for frost the following night in Wisconsin, Minnesota, and northeast Iowa. The high pressure area advanced southeastward to the lower Ohio Valley and was followed by a marked disturbance from the north Pacific. As a result frost was not reported except in the cranberry bogs of Wisconsin. The northwestern storm had reached Manitoba by the morning of the 10th, and was followed by a High from the North Pacific States. Frost warnings were issued for the entire Northwest, and as far east as central Iowa and as far south as northern Kansas, and frosts occurred the following morning as far east as western Minnesota and as far south as Nebraska. On the 11th warnings of frost or freezing temperature were issued for Montana, Wyoming, and North Dakota, and frost warnings for western Nebraska,

South Dakota, Minnesota, and northern Wisconsin, including the cranberry bogs. These warnings were verified as a rule except from southern North Dakota southward to Nebraska, where cloudiness prevailed. As high pressure and freezing temperature still prevailed over much of the Northwest, warnings were again issued on the 12th for frost in northern Minnesota and the Dakotas and for frost or freezing temperature in Montana and Wyoming. However, rain set in over much of this area and prevented frost.

The next warnings were issued on the 14th for frost in western Kansas, and frost or freezing temperature in Montana, Wyoming, western Nebraska, and extreme western South Dakota. A disturbance was advancing northeastward over the Plains States, followed by high pressure and low temperature in the northern Rocky Mountain region. The warnings were verified as a rule. On the 15th warnings were issued for frost in Montana, Wyoming, western North Dakota, Kansas, and western and central Nebraska, and for frost or freezing temperature in western South Dakota. Frost occurred as indicated except in Kansas and eastern Montana, rain falling in the latter State. As high pressure still prevailed throughout the Northwest on the 16th, frost warnings were again issued for the northern States of this district, except Montana and western Wyoming and near Lake Michigan. The warnings were verified except in central Wisconsin and in Iowa. There was little change in conditions in the Northwest on the morning of the 17th and warnings were issued for Wisconsin, Minnesota, north-central Iowa, and the eastern portions of the Dakotas. There was no frost in portions of eastern Wisconsin, northern Minnesota, and eastern North Dakota on account of cloudiness. In Iowa frost covered the whole State, except the extreme south portion.

A small area of high pressure advanced from North Dakota to the Lake region during the 19th and 20th, causing frost in the cranberry bogs of Wisconsin. Warnings of this frost were issued on the 19th. On the 21st frost warnings were issued for Wyoming, but were not verified on account of the unexpected development of a disturbance over that region. On the 22d warnings were issued for Wyoming and Montana, and were verified except in portions of Montana where cloudiness continued. The last frost warnings of the month were issued for western Wyoming on the 26th and were fully verified.—*Chas. L. Mitchell, Assistant Forecaster.*

New Orleans district.—On May 1, with the crest of an area of high pressure over eastern Colorado and low temperatures over the Plains States, frost was forecast for Oklahoma, the northern and western portions of western Texas, the northwestern portion of eastern Texas, and the extreme northern portion of Arkansas. During the ensuing 24 hours the area of high pressure greatly weakened, and although minimum temperatures of 40° or slightly higher were recorded in Oklahoma and western Texas, no frost was reported.

A small-craft warning was ordered for the Texas coast at 1:15 p. m. on May 1, as special observations indicated that the depression at the mouth of the Rio Grande River was developing in strength. The wind velocities on that afternoon showed that the warning was justified.

Frost warnings were issued for Oklahoma and the Texas Panhandle on the morning of May 3 because of an area of moderately high pressure moving southeastward from the Rocky Mountain region. In the following 24 hours the high-pressure area moved to the Gulf coast and pressure was falling rapidly over interior sections, with a well-formed low to the northward. The temperature

conditions show that the warning was justified, although frost was not reported.

Frost was forecast on May 11 for the northwestern portion of the Texas Panhandle because of low temperature northward, but a depression over the southern Plateau States extended its influence eastward and prevented frost formation.

On May 14 a decided trough of low pressure was central over Kansas, with a steep gradient and falling temperature in the rear. Frost was predicted as probable in Oklahoma, northwestern Texas, and northern central Texas. Minimum temperatures ranging from 40° to 50° occurred the following morning, but no frost was reported. This prediction was repeated on May 15 and was justified by the slight temperature fall ensuing, although frost was not reported.

From the conditions preceding and attending the wind velocities on May 18, when gales occurred at Galveston, Burrwood, and New Orleans, it would appear that these winds were due to the movement from west to east of a line of rapid pressure-falls not shown by the isobars of the weather maps. On the morning of the 18th a current velocity of 40 miles an hour from the north and a 12-hour maximum velocity of 60 miles north were recorded at Galveston. At the evening observation the 12-hour maximum velocity reported was 56 miles northeast at Galveston, while at New Orleans it was 35 miles southeast. At New Orleans, between 12:30 p. m. and 2:30 p. m. the pressure fell 0.25 inch, after which it rose gradually, the maximum velocity occurring at 1:56–2:01 p. m. Pressure developments somewhat similar occurred at Burrwood, La., where there was a maximum wind velocity of 48 miles northeast.

On May 21, because of a disturbance over Nebraska extending southward to Texas, small-craft warnings were ordered for the Texas coast at 9 a. m. and were fully verified. This disturbance was accompanied by a tornado in Oklahoma during the preceding night.

On May 24 at 8 p. m. a well-formed depression was central over the Rocky Mountain region, and the winds were fresh on the west coast of Texas. Southeast storm warnings were ordered for Texas but were lowered the next morning, as the disturbance moved northeastward and winds on the Gulf coast did not increase.—*Wm. B. Stockman, Assistant Forecaster.*

Denver district.—Frosts were common during May and severe frosts occurred much later than usual. Warnings were issued for some part of the district on the 1st to 3d, inclusive; 7th, 8th, 10th to 16th, inclusive; and 20th to 26th, inclusive. No severe frosts occurred without warnings.

On the morning of May 1 warning of frost was issued for Colorado and Utah and heavy frost in the northern and eastern portions of New Mexico. The warnings were fully verified except in the immediate vicinity of Salt Lake City. The warning of the 2d was for freezing temperature in the northeastern fourth of Colorado, while warnings for the Gunnison Valley were issued locally, based on the forecast for colder weather. The warnings were verified, the northern high having overspread the district. The warnings of the 3d for northeastern New Mexico were verified, while the warnings for local frosts in Utah and western Colorado were verified only in part, owing to the intervention of cloudiness in Utah. The warning of the 7th for frost in high districts of Utah was fully verified, but in western Colorado the warning was not generally verified, the crest of the western high pressure having advanced more rapidly than expected, and north of the district. The warning of the 8th for local

frost in Colorado and Utah was not verified, owing to the cloudiness that attended the rapid southeastward movement of a low-pressure area from the northwest. The warning of the 10th for heavy frost with freezing temperatures in localities in northern and western Colorado and Utah and heavy frost in northern New Mexico and northern Arizona was verified in the greater part of Colorado and Utah, but in New Mexico and Arizona the warning was not verified, those sections having come under the domination of a low-pressure area that developed in the extreme southwest. The warning of the 11th for frost in extreme northern Colorado and in Utah; 12th for frost in Utah; 13th for frost in western Colorado and Utah; 15th for Colorado, Utah, and northwestern New Mexico were fully verified, weather conditions in the districts indicated having remained under the controlling influence of high pressure. The warning of the 14th, the most important of the month, for heavy frost in Colorado, Utah, northern New Mexico, with freezing temperature in northeastern and southwestern Colorado, southern Utah, and northwestern New Mexico was fully verified, the HIGH in this case moving southeastward. The warning of the 16th for Colorado and New Mexico was not generally verified, owing to the cloudiness which attended the development of a LOW in the southwest. The warnings of the 20th and 21st, which were issued in anticipation of a rapid filling in of a low pressure area over Colorado, were premature and not verified. The warning of the 22d for Utah was verified, notwithstanding the fact that a LOW was in course of development in Nevada on the morning of the 23d. The further development of this LOW prevented frosts on the morning of the 24th, warnings having been issued for local frosts in western Colorado and Utah. The warnings of the 24th were for frost in northern Arizona and Utah and were fully verified, these localities coming under the influence of the front of the western HIGH. On the 25th warnings were issued for local frost in western Colorado, northern Arizona, and Utah. These were verified except in northwestern Utah. The warning of the 26th was for western Colorado and northern New Mexico, and was verified except in parts of northeastern New Mexico.—*P. H. Brandenburg, District Forecaster.*

San Francisco district.—A forecast for showers in the north portion of northern California was issued on the morning of the 6th, and the showers occurred in that section in the afternoon and night. On the morning of the 8th warnings of showers in the extreme north portion on the 9th were issued, and showers occurred in the afternoon and night of the 8th and on the 9th. Showers occurred in the north portion of northern California on the 18th without warnings, and an indefinite forecast for showers in northern California and Nevada issued on the 18th was partly verified the following night and day. Showers in Nevada on the 24th were without warnings.

A severe frost occurred in the coast valleys and delta section, with the clearing weather on the morning of the 7th, without warnings, and did considerable damage to vines. A warning of frost in exposed places in northern California was issued on the 9th, and the following morning frosts, doing considerable damage, occurred in portions of the San Joaquin valley and on the north coast.

Storm warnings were ordered 14 times during the month and were verified in nearly every instance. No verifying velocities occurred without warnings, and there was no damage to shipping.—*G. H. Willson, District Forecaster.*

Portland, Oreg., district.—No unusual characteristics were noted in connection with the weather during the first part of May, except the somewhat sudden appearance on the British Columbia coast of a marked disturbance on the evening of the 7th; its eastward movement permitted a return to normal weather conditions by the 9th. On the 10th the Pacific "High"¹ shifted northward to the coast of British Columbia, resulting in a period of fair weather with temperatures below normal and general frosts. Although this "High" hovered over the North Pacific coast during the remainder of the month, its shifting to the northern California coast and back again resulted in generally unsettled weather from the 17th on, with a considerable amount of cloudiness, abnormally low temperatures, and some local showers. The development of a marked disturbance over the Basin States on the 23d, and its subsequent leisurely eastward advance, aided very materially in bringing about the unusual weather conditions of the latter part of the month. The average daily departure from normal temperature was -2.1° .

A storm warning was issued for the Oregon coast and the mouth of the Columbia River on the evening of the 7th. The warning should have been extended to include Seattle also, where moderate to fresh gales occurred, though they were presumably in the nature of squalls and of short duration. Small-craft warnings were issued on four occasions for exposed localities in the district, and it is believed that all were verified; the one issued on the 8th should have been a storm warning for Puget Sound, as the verifying velocity was exceeded at Seattle. On the 7th the wind attained a velocity of 72 miles an hour from the southeast at North Head, Wash., but no known casualties resulted.

Four frost warnings were issued for the entire district, of which two were verified, one was partially verified, and one was a failure due to the development of cloudiness. Twelve frost warnings were issued covering part of the district, and of these, six were fully verified, three partially verified, and three were failures due to the sky becoming clouded, though in one of these instances snow resulted with a temperature of 32° . In the Rogue River Valley, where orchard heating is resorted to in order to prevent damage to fruit from low temperatures, and where we had a representative from this office in the field, our forecasts were very satisfactory; our morning weather forecasts included the information that light or heavy frosts were expected, and in the evening another telegram giving the expected minimum temperature for the "key" station at Medford was sent. The comparison of the predicted and the resulting temperatures for the dates on which frost warnings for the Rogue River Valley were issued are given here:

Dates of P. M. warnings.	Predicted temperature.	Reported minimum temperature.
	$^{\circ}F.$	$^{\circ}F.$
May 6.....	29	29
9.....	27	33
10.....	28	28
11.....	29	29
12.....	31	31
13.....	32	33

¹ The term "High" used above refers to that portion of the normal Pacific high pressure area as drawn on Weather Bureau Chart "A."

² If sky clears. On this date one of the substations located at Modoc Orchard reported a minimum temperature of 27° . The qualification "if sky clears" was necessary, as it was uncertain whether or not the cloudiness would continue throughout the night.

LIVE-STOCK WARNINGS.

Six sets of warnings were issued for expected weather conditions detrimental or dangerous to the live-stock industry, on the 6th, 10th, 17th, 20th, 22d, and 25th. These were really consecutive warnings, rather than sets, as they covered practically the entire period from the 6th to the close of the month, when there appeared no further necessity for continuing them. The following warnings were issued:

May 6, 1916.—Unsettled with local showers and cooler weather Sunday and Monday, probably clearing Tuesday and Wednesday with cold nights. Warmer last of week.

May 10, 1916.—Fair weather with cold nights and higher day temperatures indicated for remainder of week.

May 17, 1916.—Unsettled, showery, cooler weather indicated for next two or three days.

May 20, 1916.—Fair weather indicated next two or three days. Warmer days, cooler nights Monday, Tuesday.

May 22, 1916.—Unsettled with local showers indicated for next day or two. Temperatures will probably continue moderately low.

May 25, 1916.—Unsettled, partly cloudy weather to-day and Friday, probably fair, following two or three days with slowly rising temperatures.

A change in weather conditions resulting in light precipitation in live-stock districts really called for another warning on the morning of the 21st, but low temperatures and precipitation were not extreme and no reported hardship or damage occurred, and our warning of the 22d (p. m.) covered subsequent meteorological conditions. The stockmen desire advance information, when practicable, of important weather changes for better or worse, as many of them govern themselves accordingly during lambing and shearing time. The warnings have been reasonably accurate and timely, and newspaper and personal expressions of satisfaction and commendation received have been very gratifying indeed, as they indicate the practicability of this feature of Weather Bureau forecast work.—*T. Francis Drake, Local Forecaster.*